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DOI: 10.1002/bies.200900001

From Spangled Hamburghs to Turing machines: evolution – the outer reaches

Will the story of evolutionary biology culminate in a grand unifying theory of life with practical applications?

Charles Darwin was born on 12 February 1809, and it behoves BioEssays, with its strong heritage in publishing on evolution, to wish Mr Darwin a very happy 200th birthday! It was also 150 years ago this year that Charles Darwin and Alfred Russell Wallace formally announced their (practically identical) theories on evolution, and that Darwin's treatise 'On the origin of species by means of natural selection' was published. In February of that year, Darwin received the highest award from the Geographical Society, London: the Wollaston Medal for geology.

According to correspondences,[1] in February 1859 Darwin was still doing avian breeding experiments. He had just received Cochin and black-skinned fowl, which he used for studying inheritance and fertility, together with white Sussex, Dorkings and Spangled Hamburghs, among others. Little could he suspect, of course, that the traits he was studying were the result of the expression of DNA sequences, far less that 150 years later – in the case of bacteria – a living organism would be hypothetically formalised as 1) a code, which *replicates*; and 2) a machine – the Turing machine – which reads (and is capable of rewriting) the code, and which *reproduces* itself, thereby renewing the code's vehicle.[2] The laws of physics, so the theory continues, endow the system with the property of an information trap that can sequester (genetic) information, and increase that information, hence providing the prerequisite for evolutionary change – sometimes in remarkable leaps.

It appears to be a universal corollary of evolution and the physical laws underlying it that the continuum of life is a chain of ageing organisms giving rise to younger ones (and ultimately dying). The evolutionary significance of ageing was first addressed shortly after Darwin, by August Weismann[3] (1834–1914), who arguably laid the foundations for the 'disposable soma' hypothesis.[4] Today we recognise that individual organisms accumulate damage that is not passed on to their offspring. As if this weren't remarkable enough, it has recently been demonstrated that even bacteria in exponential growth phase age.[5]

And one of the next great mysteries is that of how, indeed, a thermodynamically degraded organism gives rise to a younger one,[6] using old tools, and preferentially segregating damage in the parent (as even bacteria do). If information is a fundamental measure of nature, alongside energy, mass, space and time, can the formalisation of DNA-containing organisms as 'mere' information machines (albeit complicated ones) contribute to our understanding of evolution? Might investigating the mechanism of reproductive rejuvenation shed light on how cancer cells escape senescence and death, becoming selfish propagators of their DNA?

And so, finally, to the very question of Darwin and Wallace's principle of natural selection: what, indeed, is its 'nature'? Is it, as Antoine Danchin additionally proposes, a principle *within* physics stating that all systems that use energy to make room to preserve functioning components (as opposed to degraded ones) will accumulate information? Indeed, under the correct circumstances (chemical, temperature and pressure), the laws of physics were all that was necessary to create organic molecules and structures of greater order (information content) than the surrounding inorganic environment. Such primitive entities, having acquired order by physicochemical 'happenstance', clearly preserved it at the expense of a reduction in order somewhere else in the cosmic system (hence the requirement for energy). They increasingly became distinct from the environment, acquiring ever more information to exploit it. And the discovery that genes in bacterial genomes are grouped into those essential for cellular survival and those accompanying adaptive exploitation of niches will probably give crucial insights into how to reproduce life synthetically.

This is a small selection of research topics at the very outer reaches of current evolutionary thinking, theory and application, various of which will appear in BioEssays in 'Darwin–Wallace year'. We hope this stimulates further thought-provoking contributions, correspondence and discussion. 150 years after the *Origin* was published, its topic continues to be the origin of some of the most profound questions in biology.

Andrew Moore
Editor-in-Chief

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